



TECH BRIEFS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



Technology Focus



Electronics/Computers



Software



Materials



Mechanics/Machinery



Manufacturing



Bio-Medical



Physical Sciences



Information Sciences



Books and Reports

INTRODUCTION

Tech Briefs are short announcements of innovations originating from research and development activities of the National Aeronautics and Space Administration. They emphasize information considered likely to be transferable across industrial, regional, or disciplinary lines and are issued to encourage commercial application.

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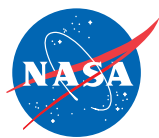
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



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Technology Focus: Mechanical Components

⚙️ Radial Internal Material Handling System (RIMS) for Circular Habitat Volumes

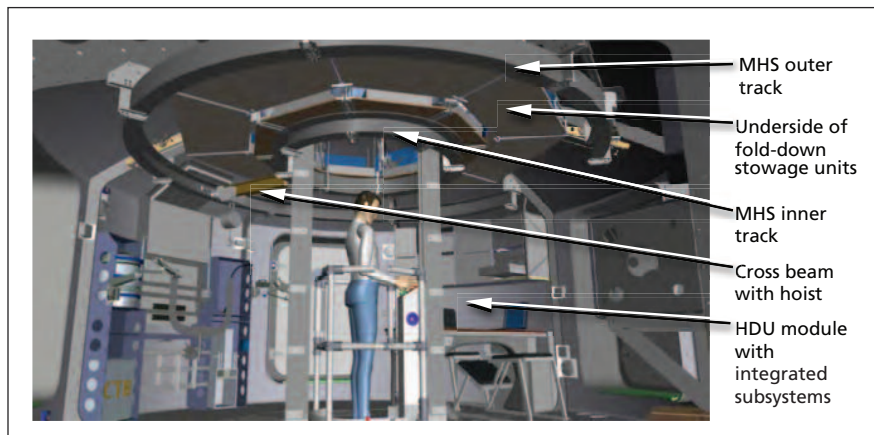
The novelty of this system is its configuration as a circular habitat.

NASA's Jet Propulsion Laboratory, Pasadena, California

On planetary surfaces, pressurized human habitable volumes will require a means to carry equipment around within the volume of the habitat, regardless of the partial gravity (Earth, Moon, Mars, etc.). On the NASA Habitat Demonstration Unit (HDU), a vertical cylindrical volume, it was determined that a variety of heavy items would need to be carried back and forth from deployed locations to the General Maintenance Work Station (GMWS) when in need of repair, and other equipment may need to be carried inside for repairs, such as rover parts and other external equipment.

The vertical cylindrical volume of the HDU lent itself to a circular overhead track and hoist system that allows lifting of heavy objects from anywhere in the habitat to any other point in the habitat interior. In addition, the system is able to hand-off lifted items to other material handling systems through the side hatches, such as through an airlock.

The overhead system consists of two concentric circle tracks that have a movable beam between them. The beam has



The HDU Material Handling System and stowage system installed on the ceiling of the habitat.

a hoist carriage that can move back and forth on the beam. Therefore, the entire system acts like a bridge crane curved around to meet itself in a circle.

The novelty of the system is in its configuration, and how it interfaces with the volume of the HDU habitat. Similar to how a bridge crane allows coverage for an entire rectangular volume, the RIMS system covers a circular volume.

The RIMS system is the first generation of what may be applied to future planetary surface vertical cylinder habitats on the Moon or on Mars.

This work was done by Alan S. Howe of Caltech; and Sally Haselschwardt, Alex Bogatko, Brian Humphrey, and Amit Patel of the University of Michigan for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48293

⚙️ Conical Seat Shut-Off Valve

This valve has applications in high-pressure and high-flow conditions.

Stennis Space Center, Mississippi

A moveable valve for controlling flow of a pressurized working fluid was designed. This valve consists of a hollow, moveable floating piston pressed against a stationary solid seat, and can use the working fluid to seal the valve. This open/closed, novel valve is able to use metal-to-metal seats, without requiring seat sliding action; therefore there are no associated damaging effects.

During use, existing standard high-pressure ball valve seats tend to become damaged during rotation of the ball. Additionally, forces acting on the ball

and stem create large amounts of friction. The combination of these effects can lead to system failure. In an attempt to reduce damaging effects and seat failures, soft seats in the ball valve have been eliminated; however, the sliding action of the ball across the highly loaded seat still tends to scratch the seat, causing failure. Also, in order to operate, ball valves require the use of large actuators. Positioning the metal-to-metal seats requires more loading, which tends to increase the size of the required actuator, and can also lead to other failures

in other areas such as the stem and bearing mechanisms, thus increasing cost and maintenance.

This novel non-sliding seat surface valve allows metal-to-metal seats without the damaging effects that can lead to failure, and enables large seating forces without damaging the valve. Additionally, this valve design, even when used with large, high-pressure applications, does not require large conventional valve actuators and the valve stem itself is eliminated. Actuation is achieved with the use of a small, simple

solenoid valve. This design also eliminates the need for many seals used with existing ball valve and globe valve designs, which commonly cause failure, too. This, coupled with the elimination of the valve stem and conventional valve actuator, improves valve reliability and seat life.

Other mechanical liftoff seats have been designed; however, they have only

resulted in increased cost, and incurred other reliability issues. With this novel design, the seat is lifted by simply removing the working fluid pressure that presses it against the seat and no external force is required.

By eliminating variables associated with existing ball and globe configurations that can have damaging effects upon a valve, this novel design reduces

downtime in rocket engine test schedules and maintenance costs.

This work was done by Bruce Farner of Stennis Space Center, (U.S. Patent #8,336,849), and is available for licensing. For more information contact the SSC Office of the Center Chief Technologist at (228) 688-1929 or by e-mail SSC-Technology@nasa.gov. Refer to SSC-00264.

✱ Impact-Actuated Digging Tool for Lunar Excavation

John F. Kennedy Space Center, Florida

NASA's plans for a lunar outpost require extensive excavation. The Lunar Surface Systems Project Office projects that thousands of tons of lunar soil will need to be moved. Conventional excavators dig through soil by brute force, and depend upon their substantial weight to react to the forces generated. This approach will not be feasible on the Moon for two reasons: (1) gravity is 1/6th that on Earth, which means that a kg on the Moon will supply 1/6 the down force that it does on Earth, and (2) transportation costs (at the time of this reporting) of \$50K to \$100K per kg make massive excavators economically unattractive.

A percussive excavation system was developed for use in vacuum or near-vacuum environments. It reduces the

down force needed for excavation by an order of magnitude by using percussion to assist in soil penetration and digging. The novelty of this excavator is that it incorporates a percussive mechanism suited to sustained operation in a vacuum environment.

A percussive digger breadboard was designed, built, and successfully tested under both ambient and vacuum conditions. The breadboard was run in vacuum to more than 2 times the lifetime of the Apollo Lunar Surface Drill, throughout which the mechanism performed and held up well. The percussive digger was demonstrated to reduce the force necessary for digging in lunar soil simulant by an order of magnitude, providing reductions as high as 45:1.

This is an enabling technology for lunar site preparation and ISRU (In Situ Resource Utilization) mining activities. At transportation costs of \$50K to \$100K per kg, reducing digging forces by an order of magnitude translates into billions of dollars saved by not launching heavier systems to accomplish excavation tasks necessary to the establishment of a lunar outpost. Applications on the lunar surface include excavation for habitats, construction of roads, landing pads, berms, foundations, habitat shielding, and ISRU.

This work was done by Jack Wilson, Philip Chu, Jack Craft, Kris Zacny, and Chris Santoro of Honeybee Robotics Ltd. for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Program Office at (321) 861-7158. KSC-13398

✱ Flexible Mechanical Conveyors for Regolith Extraction and Transport

John H. Glenn Research Center, Cleveland, Ohio

A report describes flexible mechanical conveying systems for transporting fine cohesive regolith under microgravity and vacuum conditions. They are totally enclosed, virtually dust-free, and can include enough flexibility in the conveying path to enable an expanded range of extraction and transport scenarios, including nonlinear drill-holes and excavation of enlarged subsurface openings without large entry holes.

The design of the conveyors is a modification of conventional screw conveyors such that the central screw-shaft

and the outer housing or conveying-tube have a degree of bending flexibility, allowing the conveyors to become nonlinear conveying systems that can convey around gentle bends. The central flexible shaft is similar to those used in common tools like a "weed whacker," consisting of multiple layers of tightly wound wires around a central wire core.

Utilization of compliant components (screw blade or outer wall) increases the robustness of the conveying, allowing an occasional oversized particle to pass

though the conveyor without causing a jam or stoppage.

This work was done by Otis R. Walton and Hubert J. Vollmer of Grainflow Dynamics Inc., and Ali Abdel-Hadi of Tuskegee University for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-19015-1.



Remote Memory Access Protocol Target Node Intellectual Property

Goddard Space Flight Center, Greenbelt, Maryland

The MagnetoSpheric Multiscale (MMS) mission had a requirement to use the Remote Memory Access Protocol (RMAP) over its SpaceWire network. At the time, no known intellectual property (IP) cores were available for purchase. Additionally, MMS preferred to implement the RMAP functionality with control over the low-level details of the design. For example, not all the RMAP standard functionality was needed, and it was desired to implement only the portions of the RMAP protocol that were needed. RMAP functionality had been previously implemented in commercial off-the-shelf (COTS) products, but the IP core was not available for purchase.

The RMAP Target IP core is a VHDL (VHSIC Hardware Description Lan-

guage) description of a digital logic design suitable for implementation in an FPGA (field-programmable gate array) or ASIC (application-specific integrated circuit) that parses SpaceWire packets that conform to the RMAP standard. The RMAP packet protocol allows a network host to access and control a target device using address mapping. This capability allows SpaceWire devices to be managed in a standardized way that simplifies the hardware design of the device, as well as the development of the software that controls the device.

The RMAP Target IP core has some features that are unique and not specified in the RMAP standard. One such feature is the ability to automatically abort transactions if the back-end logic

does not respond to read/write requests within a predefined time. When a request times out, the RMAP Target IP core automatically retracts the request and returns a command response with an appropriate status in the response packet's header. Another such feature is the ability to control the SpaceWire node or router using RMAP transactions in the extended address range. This allows the SpaceWire network host to manage the SpaceWire network elements using RMAP packets, which reduces the number of protocols that the network host needs to support.

This work was done by Omar Haddad of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16467-1

Soft Decision Analyzer

An in-depth insight of a communication system's receiver performance is provided in a variety of operating conditions.

Lyndon B. Johnson Space Center, Houston, Texas

The Soft Decision Analyzer (SDA) is an instrument that combines hardware, firmware, and software to perform real-time closed-loop end-to-end statistical analysis of single- or dual-channel serial digital RF communications systems operating in very low signal-to-noise conditions. As an innovation, the unique SDA capabilities allow it to perform analysis of situations where the receiving communication system slips bits due to low signal-to-noise conditions or experiences constellation rotations resulting in channel polarity in versions or channel assignment swaps. SDA's closed-loop detection allows it to instrument a live system and correlate observations with frame, codeword, and packet losses, as well as Quality of Service (QoS) and Quality of Experience (QoE) events. The SDA's abilities are not confined to performing analysis in low signal-to-noise conditions. Its analysis provides in-

depth insight of a communication system's receiver performance in a variety of operating conditions.

The SDA incorporates two techniques for identifying slips. The first is an examination of content of the received data stream's relation to the transmitted data content and the second is a direct examination of the receiver's recovered clock signals relative to a reference. Both techniques provide benefits in different ways and allow the communication engineer evaluating test results increased confidence and understanding of receiver performance. Direct examination of data contents is performed by two different data techniques, power correlation or a modified Massey correlation, and can be applied to soft decision data widths 1 to 12 bits wide over a correlation depth ranging from 16 to 512 samples. The SDA detects receiver bit slips within a ± 4 bits window and can handle

systems with up to four quadrants (QPSK, SQPSK, and BPSK systems). The SDA continuously monitors correlation results to characterize slips and quadrant change and is capable of performing analysis even when the receiver under test is subjected to conditions where its performance degrades to high error rates (30 percent or beyond). The design incorporates a number of features, such as watchdog triggers that permit the SDA system to recover from large receiver upsets automatically and continue accumulating performance analysis unaided by operator intervention. This accommodates tests that can last in the order of days in order to gain statistical confidence in results and is also useful for capturing snapshots of rare events.

Slip and quadrant performance are displayed in real time in addition to being logged for later analysis. The SDA pro-

vides methods of evaluating the significance of BER (bit error rate) test results as well as techniques to characterize imbalances due to inter-symbol interference or inter-channel interference. Techniques employed in the SDA provide a means to statistically characterize receiver performance efficiently using a minimum of accumulated test results with a definable level

of error. These advanced techniques have broad application to other fields that rely on evaluation of binomial experiments (pass/fail, true/false, go/no-go), and allow evaluators to extract more information from fewer trials.

This work was done by Glen Steele, Chatwin Lansdowne, Joan Zucha, and Adam Schlesinger of Johnson Space Center. For fur-

ther information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-1003. Refer to MSC-24798-1.

Distributed Prognostics and Health Management With a Wireless Network Architecture

Distributed architectures prevent total system failure during emergencies, allowing parts of the system to continue to function, and making overall system recovery faster.

Ames Research Center, Moffett Field, California

A heterogeneous set of system components monitored by a varied suite of sensors and a particle-filtering (PF) framework, with the power and the flexibility to adapt to the different diagnostic and prognostic needs, has been developed. Both the diagnostic and prognostic tasks are formulated as a particle-filtering problem in order to explicitly represent and manage uncertainties in state estimation and remaining life estimation. Current state-of-the-art prognostic health management (PHM) systems are mostly centralized in nature, where all the processing is reliant on a single processor. This can lead to a loss in functionality in case of a crash of the central processor or monitor. Furthermore, with increases in the volume of sensor data as well as the complexity of algorithms, traditional centralized systems become — for a number of reasons — somewhat ungainly for successful deployment, and efficient distributed architectures can be more beneficial.

The distributed health management architecture is comprised of a network of smart sensor devices. These devices monitor the health of various subsystems or modules. They perform diagnostics operations and trigger prognostics operations based on user-defined thresholds and rules. The sensor devices, called computing elements (CEs), consist of a sensor, or set of sensors, and a communication device (i.e., a wireless transceiver beside an embedded processing element). The CE runs in either a diagnostic or prognostic operating mode. The diagnostic mode is the default mode where a CE monitors a given subsystem or component through a low-weight diagnostic algorithm. If a CE detects a critical condition during monitoring, it raises a flag. Depending on availability of resources, a networked local cluster of CEs is formed that then carries out prognostics and fault mitigation by efficient distribution of the tasks. It should be

noted that the CEs are expected not to suspend their previous tasks in the prognostic mode. When the prognostics task is over, and after appropriate actions have been taken, all CEs return to their original default configuration.

Wireless technology-based implementation would ensure more flexibility in terms of sensor placement. It would also allow more sensors to be deployed because the overhead related to weights of wired systems is not present. Distributed architectures are furthermore generally robust with regard to recovery from node failures.

This work was done by Kai Goebel of Ames Research Center, and Sankalita Saha and Bhaskar Sha of Mission Critical Technologies, Inc.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at 1-855-NASA-BIZ (1-855-6272-249). Refer to ARC-16450-1.

Minimal Power Latch for Single-Slope ADCs

A CMOS implementation for remote sensing applications results in further reduction of power consumption and noise.

NASA's Jet Propulsion Laboratory, Pasadena, California

Column-parallel analog-to-digital converters (ADCs) for imagers involve simultaneous operation of many ADCs. Single-slope ADCs are well adapted to this use because of their simplicity. Each ADC contains a comparator, comparing its input signal level to an increasing reference signal (ramp). When the ramp is

equal to the input, the comparator triggers a latch that captures an encoded counter value (code). Knowing the captured code, the ramp value and hence the input signal are determined. In a column-parallel ADC, each column contains only the comparator and the latches; the ramp and code generation

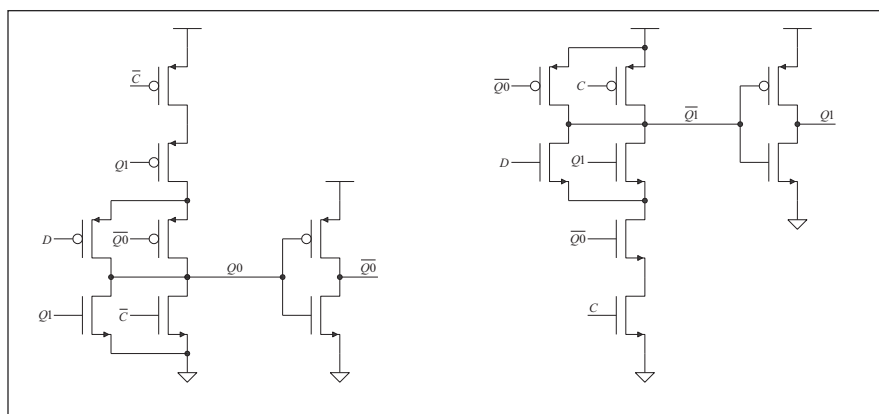
are shared.

In conventional latch or flip-flop circuits, there is an input stage that tracks the input signal, and this stage consumes switching current every time the input changes. With many columns, many bits, and high code rates, this switching current can be substantial. It

will also generate noise that may corrupt the analog signals. A latch was designed that does not track the input, and consumes power only at the instant of latching the data value.

The circuit consists of two S-R (set-reset) latches, gated by the comparator. One is set by high data values and the other by low data values. The latches are cross-coupled so that the first one to set blocks the other. In order that the input data not need an inversion, which would consume power, the two latches are made in complementary polarity. This requires complementary gates from the comparator, instead of complementary data values, but the comparator only triggers once per conversion, and usually has complementary outputs to begin with.

An efficient CMOS (complementary metal oxide semiconductor) implementation of this circuit is shown in the figure, where C is the comparator output, D is the data (code), and $Q0$ and $Q1$ are the outputs indicating the capture of a zero or one value. The latch for $Q0$ has a negative-true set signal and output, and is implemented using OR-AND-INVERT logic, while the latch for $Q1$ uses positive-true signals and is implemented using AND-OR-INVERT logic. In this im-



An implementation of the **Minimal Power Latch** using complex logic gates.

plementation, both latches are cleared when the comparator is reset. Two redundant transistors are removed from the reset side of each latch, making for a compact layout.

CMOS imagers with column-parallel ADCs have demonstrated high performance for remote sensing applications. With this latch circuit, the power consumption and noise can be further reduced. This innovation can be used in CMOS imagers and very-low-power electronics.

This work was done by Bruce R. Hancock of Caltech for NASA's Jet Propulsion Laboratory.

Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-48007, volume and number of this NASA Tech Briefs issue, and the page number.



Bismuth Passivation Technique for High-Resolution X-Ray Detectors

Goddard Space Flight Center, Greenbelt, Maryland

The Athena-plus team requires X-ray sensors with energy resolution of better than one part in 3,000 at 6 keV X-rays. While bismuth is an excellent material for high X-ray stopping power and low heat capacity (for large signal when an X-ray is stopped by the absorber), oxidation of the bismuth surface can lead to electron traps and other effects that degrade the energy resolution. Bismuth oxide reduction and nitride passivation techniques analogous to those used in indium passivation are being applied in a new technique. The technique will enable improved energy resolution and resistance to aging in bismuth-absorber-coupled X-ray sensors.

Elemental bismuth is lithographically integrated into X-ray detector circuits. It encounters several steps where the Bi oxidizes. The technology discussed here will remove oxide from the surface of the Bi and replace it with nitridized surface. Removal of the native oxide and passivating to prevent the growth of the oxide will improve detector performance and insulate the detector against future degradation from oxide growth. Placing the Bi coated sensor in a vacuum system, a reduction chemistry in a plasma (nitrogen/hydrogen (N_2/H_2) + argon) is used to remove the oxide and promote nitridization of the cleaned Bi surface. Once

passivated, the Bi will perform as a better X-ray thermalizer since energy will not be trapped in the bismuth oxides on the surface.

A simple additional step, which can be added at various stages of the current fabrication process, can then be applied to encapsulate the Bi film. After plasma passivation, the Bi can be capped with a non-diffusive layer of metal or dielectric. A non-superconducting layer is required such as tungsten or tungsten nitride (WN_x).

This work was done by James Chervenak and Larry Hess of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16383-1



High-Strength, Superelastic Compounds

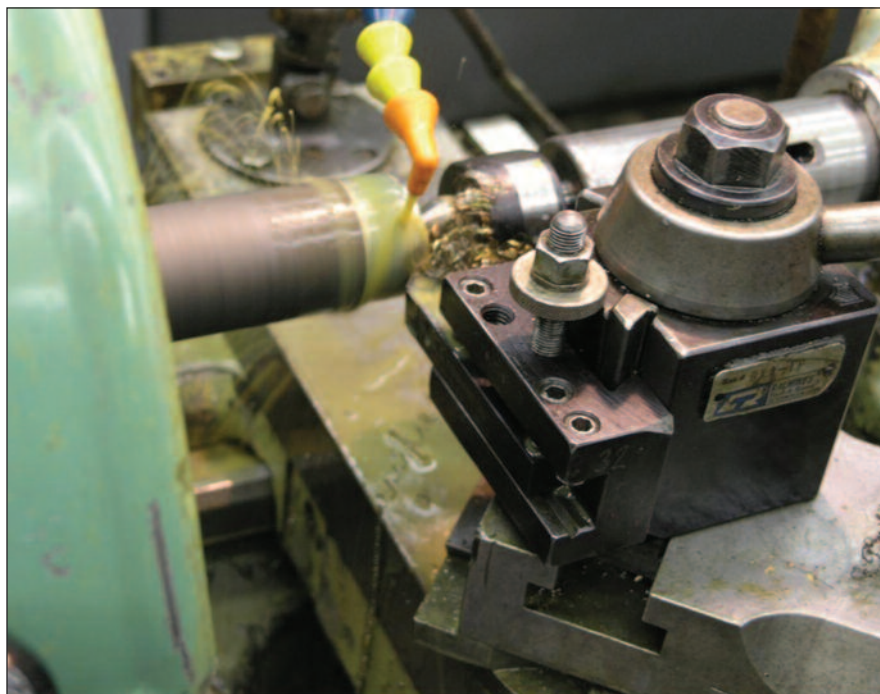
A new ordered intermetallic compound reduces costs, increases performance, and prevents cracking and distortion during thermal processing.

John H. Glenn Research Center, Cleveland, Ohio

In a previous disclosure, the use of 60-NiTiNOL, an ordered intermetallic compound composed of 60 weight percent nickel and 40 weight percent titanium, was investigated as a material for advanced aerospace bearings due to its unique combination of physical properties. Lessons learned during the development of applications for this material have led to the discovery that, with the addition of a ternary element, the resulting material can be thermally processed at a lower temperature to attain the same desirable hardness level as the original material. Processing at a lower temperature is beneficial, not only because it reduces processing costs from energy consumption, but because it also significantly reduces the possibility of quench cracking and thermal distortion, which have been problematic with the original material. A family of ternary substitutions has been identified, including Hf and Zr in various atomic percentages with varying concentrations of Ni and Ti.

In the present innovation, a ternary intermetallic compound consisting of 57.6 weight percent Ni, 39.2 weight percent Ti, and 3.2 weight percent Hf (54Ni-45Ti-1Hf atomic percent) was prepared by casting. In this material, Hf substitutes for some of the Ti atoms in the material. In an alternate embodiment of the innovation, Zr, which is close in chemical behavior to Hf, is used as the substitutional element. With either substitution, the solvus temperature of the material is reduced, and lower temperatures can be used to obtain the necessary hardness values.

The advantages of this innovation include the ability to solution-treat the material at a lower temperature and still achieve the required hardness for bearings (at least 50 Rockwell C) and superelastic behavior with recoverable strains greater than 2%. Most structural alloys will not return to their original shape after being deformed as little as 0.2% (a tenth of that possible with superelastic materials like 60 NiTiNOL). Because



The Modified NiTiNOL being machined in a lathe.

lower temperatures can be used in the heat treatment process, less energy will be consumed, and there will be less dimensional distortion and quench cracking. This results in fewer scrap parts, less material waste from large amounts of material removal, and fewer machining steps to rework parts that are out of specification.

This material has a combination of properties that have been previously un-

obtainable. The material has a Young's modulus of approximately 95 GPa (about half that of conventional steels), moderate density (10 to 15% lower than conventional steels), excellent corrosion resistance, and high hardness (58 to 62 HRC). These properties make this material uniquely suited for advanced bearings.

This work was done by Malcolm Stanford, Ronald Noebe, Christopher Dellacorte, Glen

Bigelow, and Fransua Thomas of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-19029-1. t

Cu-Cr-Nb-Zr Alloy for Rocket Engines and Other High-Heat-Flux Applications

Applications include high-temperature, high-efficiency industrial heat exchangers, welding electrodes, and head gaskets for automobile racing engines.

John H. Glenn Research Center, Cleveland, Ohio

Rocket-engine main combustion chamber liners are used to contain the burning of fuel and oxidizer and provide a stream of high-velocity gas for propulsion. The liners in engines such as the Space Shuttle Main Engine are regeneratively cooled by flowing fuel, e.g., cryogenic hydrogen, through cooling channels in the back side of the liner. The heat gained by the liner from the flame and compression of the gas in the throat section is transferred to the fuel by the liner. As a result, the liner must either have a very high thermal conductivity or a very high operating temperature.

In addition to the large heat flux (>10 MW/m²), the liners experience a very large thermal gradient, typically more than 500 °C over 1 mm. The gradient produces thermally induced stresses and strains that cause low cycle fatigue (LCF). Typically, a liner will experience a strain differential in excess of 1% between the cooling channel and the hot wall. Each time the engine is fired, the liner undergoes an LCF cycle. The number of cycles can be as few as one for an expendable booster engine, to as

many as several thousand for a reusable launch vehicle or reaction control system. Finally, the liners undergo creep and a form of mechanical degradation called thermal ratcheting that results in the bowing out of the cooling channel into the combustion chamber, and eventual failure of the liner.

GRCop-84, a Cu-Cr-Nb alloy, is generally recognized as the best liner material available at the time of this reporting. The alloy consists of 14% Cr₂Nb precipitates in a pure copper matrix. Through experimental work, it has been established that the Zr will not participate in the formation of Laves phase precipitates with Cr and Nb, but will instead react with Cu to form the desired Cu-Zr compounds. It is believed that significant improvements in the mechanical properties of GRCop-84 will be realized by adding Zr. The innovation is a Cu-Cr-Nb-Zr alloy covering the composition range of 0.8 to 8.1 weight percent Cr, 0.7 to 7.2 weight percent Nb, 0.1 to 1.5 weight percent Zr, and balance Cu.

The alloy combines two known strengthening mechanisms — dispersion strengthening by Cr₂Nb precipitates (GRCop-84), and precipitation strengthening by Cu_xZr (AMZIRC) — to produce a synergistic increase in the capabilities of the alloy with the goal of achieving properties greater than either of the methods could achieve alone. The anticipated advantages of the alloy are higher strength at temperatures up to 700 °C, improved creep strength, and significantly higher LCF lives relative to GRCop-84. The thermal expansion, thermal conductivity, and processing of the alloy are anticipated to remain largely unchanged relative to GRCop-84.

This work was done by David L. Ellis of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18136-1.

Microgravity Storage Vessels and Conveying-Line Feeders for Cohesive Regolith

This design may provide a reliable, robust method for filling pharmaceutical capsules with fine, dry powders.

John H. Glenn Research Center, Cleveland, Ohio

Under microgravity, the usual methods of placing granular solids into, or extracting them from, containers or storage vessels will not function. Alternative

methods are required to provide a motive force to move the material. New configurations for microgravity regolith storage vessels that do not resemble ter-

restrial silos, hoppers, or tanks are proposed. The microgravity-compatible bulk-material storage vessels and exit-feed configurations are designed to reli-

ably empty and feed cohesive material to transfer vessels or conveying ducts or lines without gravity. A controllable motive force drives the cohesive material to the exit opening(s), and provides a reliable means to empty storage vessels and/or to feed microgravity conveying lines. The proposed designs will function equally well in vacuum, or inside of pressurized enclosures.

Typical terrestrial granular solids handling and storage equipment will not function under microgravity, since almost all such equipment relies on gravity to at least move material to an exit location or to place it in the bottom of a container. Under microgravity, there effectively are no directions of up or down, and in order to effect movement of material, some other motive force must be applied to the material. The proposed storage vessels utilize dynamic centrifugal force to effect movement of regolith whenever material needs to be removed from the storage vessel. During simple storage, no dynamic motion or forces are required. The rotation rate during emptying can be controlled to ensure that material will move to the desired exit opening, even if the material is highly cohesive, or has acquired an electrostatic charge.

The general concept of this Swirl Action Utilized for Centrifugal Ejection of Regolith (SAUCER) microgravity stor-

age unit/dynamic feeder is to have an effective slot-hopper (based on the converging angles of the top and bottom conical section of the vessel) with an exit slot around the entire periphery of the SAUCER. The basic shape of such a unit is like two Chinese straw hats (douli) — one upside down, on the bottom, and another on top; or two wok-pans, one upright on the bottom and another inverted on top, with a small gap between the upright and inverted pans or hats (around the periphery). A stationary outer ring, much like an unmounted bicycle tire, surrounds the gap between the two coaxial, nearly conical pieces, forming the top and bottom of the unit.

When the entire unit is spun around its axis, centrifugal forces will exceed the cohesive arch strength of the regolith inside (at some rotational speed), and some material will be ejected through the peripheral slot into the surrounding stationary ring. Multiple small brushes or blades will sweep the extruded material around inside the enclosing stationary ring (tire). A circular hole in the outer ring allows the swirling material to pass through the outer ring wall and into an attached screw conveyor or other unit. Because the opening in the outer ring is circular, there is no preferred orientation for an attached screw conveyor, other than that it would work best if its

axis lies in a plane tangent to the outer circumference of the ring. The ring and screw conveyor remain in a fixed orientation, while the top and bottom cones of the SAUCER are connected together (with a gap between them) and rotate about their common axis to produce the centrifugal force, enabling the material inside the SAUCER to be ejected through the outer slot or gap into the dispensing ring. The screw conveyor picks up the material swept through the hole in the outer ring.

Without an externally supplied motive force, a cohesive granular solid will not move under microgravity, but will remain in an open container, independent of the container's orientation, until an external force causes the material to move. The controllable centrifugal force of the proposed SAUCER design provides a rational solution for storage and subsequent emptying of vessels containing cohesive granular solids under microgravity or low-gravity conditions.

This work was done by Otis R. Walton and Hubert J. Vollmer of Grainflow Dynamics, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-19016-1.



CRUQS: A Miniature Fine Sun Sensor for Nanosatellites

Size, mass, and power make the sensor suited to small satellite applications, especially nanosatellites.

Goddard Space Flight Center, Greenbelt, Maryland

A new miniature fine Sun sensor has been developed that uses a quadrant photodiode and housing to determine the Sun vector. Its size, mass, and power make it especially suited to small satellite applications, especially nanosatellites. Its accuracy is on the order of one arc-minute, and it will enable new science in the area of nanosatellites.

The motivation for this innovation was the need for high-performance Sun sensors in the nanosatellite category. The design idea comes out of the LISS (Lockheed Intermediate Sun Sensor) used by the sounding rocket program on their solar pointing ACS (Attitude Control System). This system uses photodiodes and a wall between them. The shadow cast by the Sun is used to determine the Sun angle. The new sensor

takes this concept and miniaturizes it. A cruciform shaped housing and a surface-mount quadrant photodiode package allow for a two-axis fine Sun sensor to be packaged into a space $\approx 1.25 \times 1 \times 0.25$ in. ($\approx 3.2 \times 2.5 \times 0.6$ cm). The circuitry to read the photodiodes is a simple transimpedance operational amplifier. This is much less complex than current small Sun sensors for nanosatellites that rely on photoarrays and processing of images to determine the Sun center. The simplicity of the circuit allows for a low power draw as well.

The sensor consists of housing with a cruciform machined in it. The cruciform walls are 0.5-mm thick and the center of the cruciform is situated over the center of the quadrant photodiode sensor. This allows for shadows to be cast on

each of the four photodiodes based on the angle of the Sun. A simple operational amplifier circuit is used to read the output of the photodiodes as a voltage. The voltage output of each photodiode is summed based on rows and columns, and then the values of both rows or both columns are differenced and divided by the sum of the voltages for all four photodiodes. The value of both difference over sums for the rows and columns is compared to a table or a polynomial fit (depending on processor power and accuracy requirements) to determine the angle of the Sun in the sensor frame.

This work was done by Scott Heatwole, Carl Snow, and Luis Santos of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16551-1

On-Chip Microfluidic Components for In Situ Analysis, Separation, and Detection of Amino Acids

This innovation can be integrated in a lab-on-a-chip device for biological and analytical instruments.

Goddard Space Flight Center, Greenbelt, Maryland

The Astrobiology Analytical Laboratory at GSFC has identified amino acids in meteorites and returned cometary samples by using liquid chromatography-electrospray ionization time-of-flight mass spectrometry (LCMS). These organic species are key markers for life, having the property of chirality that can be used to distinguish biological from non-biological amino acids. One of the critical components in the benchtop instrument is liquid chromatography (LC) analytical column. The commercial LC analytical column is an over-250-mm-long and 4.6-mm-diameter stainless steel tube filled with functionized microbeads as stationary phase to separate the molecular species based on their chemistry. Miniaturization of this technique for spaceflight is compelling for future payloads for landed missions targeting astrobiology objectives.

A commercial liquid chromatography analytical column consists of an inert cylindrical tube filled with a stationary phase, i.e., microbeads, that has been functionalized with a targeted chemistry. When analyte is sent through the column by a pressurized carrier fluid (typically a methanol/water mixture), compounds are separated in time due to differences in chemical interactions with the stationary phase. Different species of analyte molecules will interact more strongly with the column chemistry, and will therefore take longer to traverse the column. In this way, the column will separate molecular species based on their chemistry.

A lab-on-chip liquid analysis tool was developed. The microfluidic analytical column is capable of chromatographi-

cally separating biologically relevant classes of molecules based on their chemistry. For this analytical column, fabrication, low leak rate, and stationary phase incorporation of a serpentine microchannel were demonstrated that mimic the dimensions of a commercial LC column within a $5 \times 10 \times 1$ mm chip. The microchannel in the chip has a 75-micrometer-diameter oval-shaped cross section. The serpentine microchannel has four different lengths: 40, 60, 80, and 100 mm. Functionized microbeads were filled inside the microchannel to separate molecular species based on their chemistry.

This microscale analytic chip is designed to integrate with miniaturized liquid chromatography/mass spectrometry for in situ analysis, separation, and detection of biologically relevant classes of

molecules, which may provide clues about the presence of past or extant biology. GSFC has successfully demonstrated that the microfluidic analytical chip is able to separate the amino acids glycine and leucine, as well as the chiral amino acids L-valine and D-valine.

The microscale liquid chromatography analytic column is suitable for miniaturized liquid chromatography and mass spectrometry. Its serpentine microchannel in the microfluidic chip

provides up to 100-mm length for analyte molecules interacting in the column. The 100-mm length of microchannel is compatible with commercial analytic column for better separation. It is easy to integrate other electronic devices on the chip such as a micro heater and temperature sensor to monitor and control liquid temperature. The chip can stand up to 4,000 psi (≈ 27.6 MPa) pressure, which is much higher than a polymer-made lab-on-a-

chip. Silicon and Pyrex microchannels can be used in a wide range of solutions, including strong acid and base solutions. It will not contaminate the analyte molecules. Also, the cost of the microscale analytic column is much less than a commercial column.

This work was done by Yun Zheng, Stephanie Getty, Jason Dworkin, Manuel Balvin, and Carl Kotecki of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16517-1

Spectroscopic Determination of Trace Contaminants in High-Purity Oxygen

A glow discharge emission system is used to detect and quantify trace amounts of argon in pure oxygen.

Lyndon B. Johnson Space Center, Houston, Texas

Oxygen used for extravehicular activities (EVAs) must be free of contaminants because a difference in a few tenths of a percent of argon or nitrogen content can mean significant reduction in available EVA time. These inert gases build up in the extravehicular mobility unit because they are not metabolized or scrubbed from the atmosphere. A prototype optical emission technique capable of detecting argon and nitrogen below 0.1% in oxygen has been developed. This instrument uses a glow discharge in reduced-pressure gas to produce atomic emission from the species present. Because the atomic emission lines from oxygen, nitrogen, and argon are discrete, and in many cases well-separated, trace amounts of argon and nitrogen can be detected in the ultraviolet and visible spectrum. This is a straightforward, direct measurement of the target contaminants, and may lend itself to a device capable of on-orbit verification of oxygen purity.

A glow discharge is a plasma formed in a low-pressure (1 to 10 Torr) gas cell between two electrodes. Depending on the configuration, voltages ranging from 200 V and above are required to sustain the discharge. In the discharge region, the gas is ionized and a certain population is in the excited state. Light is produced by the transitions from the excited states formed in the plasma to the ground state. The spectrum consists of discrete, narrow emission lines for the atomic species, and broader peaks that may appear as a manifold for molecular species such as O_2 and N_2 , the wave-

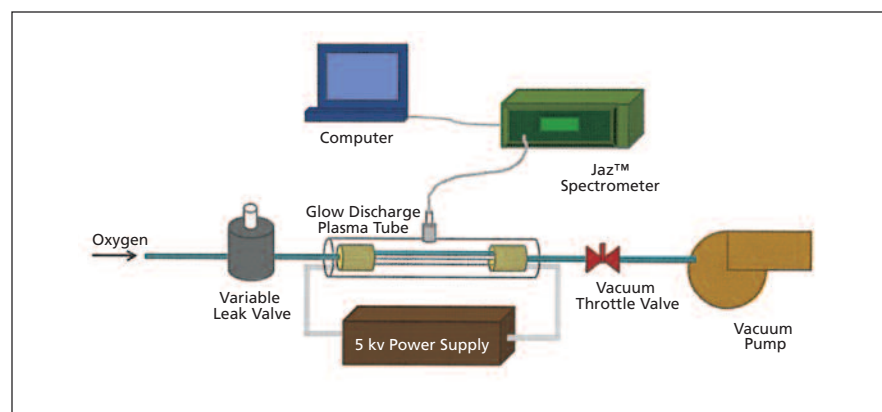


Figure 1. A schematic diagram of the Glow Discharge System.

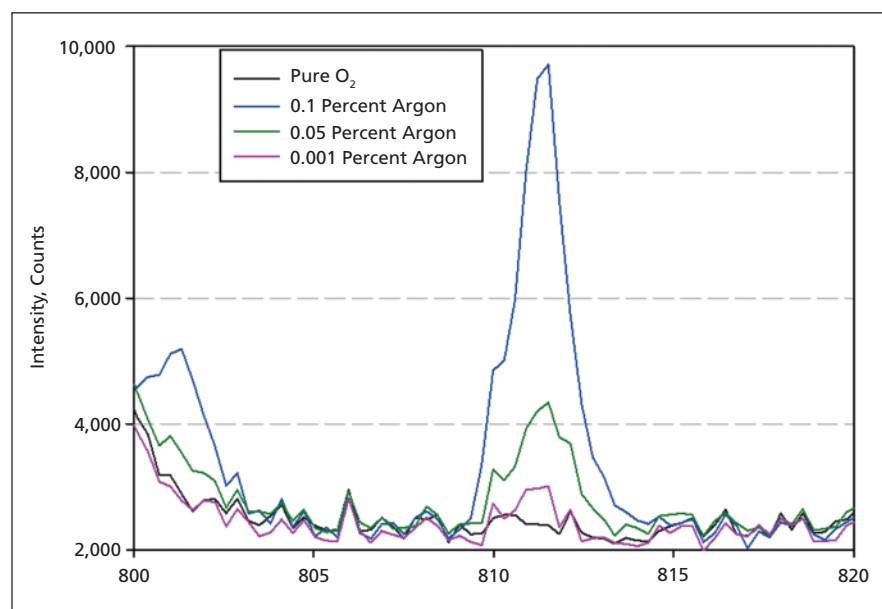


Figure 2. Region around 811-nm argon shows Peak for Pure Oxygen and 0.1, 0.05, and 0.01 percent argon in oxygen.

lengths and intensities of which are a characteristic of each atom. The oxygen emission is dominated by two peaks at 777 and 844 nm.

For testing, a quartz capillary tube with stainless steel end fittings forms the glow discharge tube. The sample gas is introduced into the glow discharge cell using an adjustable vacuum leak valve. From the glow discharge cell, the sample gas passes a vacuum gauge, the downstream valve, and then the vacuum pump. During operation, the pressure in the glow discharge cell is maintained between 0.5 and 10 Torr using the adjustable leak valve and the downstream valve. Light from the discharge is collected by a lens and coupled to a UV-visible fiber-optic cable. This cable directs the light from the glow discharge into a

spectrometer. The spectrometer detects in the 200- to 850-nm region with a spectral resolution of 1.5 nm using a 25- μ m entrance slit. The spectrometer is connected to a data acquisition computer via a USB cable. For this work, Ocean Optics' SpectraSuite[®] software was used for the data acquisition, setting parameters such as wavelength range, integration times, and scans to average.

For a peak to be at the detection limit, it must be recognizable as a peak, be resolved from other peaks, and have a peak intensity three times the standard deviation of background noise in the region of the peak. The peak corresponding to 0.01% argon is just above the baseline of pure oxygen (see Figure 2), and the signal-to-noise ratio is 2.6, indicating the detection limit is between

0.05 and 0.01%.

This work represents a proof-of-concept investigation into using a glow discharge emission system to detect and quantitate trace amounts of argon in pure oxygen. A similar analysis will need to be done for nitrogen. Optimization of experimental parameters such as operating pressure, discharge current, voltage, and spectrometer integration time needs to be further investigated. A redesigned discharge cell that will use a lower-voltage DC power supply with a higher discharge current is being designed to provide a spectrally brighter, lower-noise glow discharge.

This work was done by Steven Hornung of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-25116

Method of Separating Oxygen From Spacecraft Cabin Air to Enable Extravehicular Activities

Lyndon B. Johnson Space Center, Houston, Texas

Extravehicular activities (EVAs) require high-pressure, high-purity oxygen. Shuttle EVAs use oxygen that is stored and transported as a cryogenic fluid. EVAs on the International Space Station (ISS) presently use the Shuttle cryo O₂, which is transported to the ISS using a transfer hose. The fluid is compressed to elevated pressures and stored as a high-pressure gas. With the retirement of the shuttle, NASA has been searching for ways to deliver oxygen to fill the high-pressure oxygen tanks on the ISS.

A method was developed using low-pressure oxygen generated onboard the ISS and released into ISS cabin air, filtering the oxygen from ISS cabin air using

a pressure swing absorber to generate a low-pressure (high-purity) oxygen stream, compressing the oxygen with a mechanical compressor, and transferring the high-pressure, high-purity oxygen to ISS storage tanks. The pressure swing absorber (PSA) can be either a two-stage device, or a single-stage device, depending on the type of sorbent used. The key is to produce a stream with oxygen purity greater than 99.5 percent. The separator can be a PSA device, or a VPSA device (that uses both vacuum and pressure for the gas separation). The compressor is a multi-stage mechanical compressor. If the gas flow rates are on the order of 5 to 10 lb ($\approx$ 2.3 to 4.6 kg)

per day, the compressor can be relatively small [3 $\times$ 16 $\times$ 16 in. ($\approx$ 8 $\times$ 41 $\times$ 41 cm)].

Any spacecraft system, or other remote location that has a supply of low-pressure oxygen, a method of separating oxygen from cabin air, and a method of compressing the enriched oxygen stream, has the possibility of having a regenerable supply of high-pressure, high-purity oxygen that is compact, simple, and safe. If cabin air is modified so there is very little argon, the separator can be smaller, simpler, and use less power.

This work was done by John C. Graf of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24806-1

Atomic Force Microscope Mediated Chromatography

Trace-chemical and microfluidic analyses are taken to higher precision.

NASA's Jet Propulsion Laboratory, Pasadena, California

The atomic force microscope (AFM) is used to inject a sample, provide shear-driven liquid flow over a functionalized substrate, and detect separated components. This is demonstrated using lipophilic dyes and normal phase chromatography. A significant reduction in both size and separation time scales is achieved with a 25-micron-length col-

umn scale, and one-second separation times. The approach has general applications to trace chemical and microfluidic analysis.

The AFM is now a common tool for ultra-microscopy and nanotechnology. It has also been demonstrated to provide a number of microfluidic functions necessary for miniaturized chromatography.

These include injection of sub-femtoliter samples, fluidic switching, and shear-driven pumping. The AFM probe tip can be used to selectively remove surface layers for subsequent microchemical analysis using infrared and tip-enhanced Raman spectroscopy. With its ability to image individual atoms, the AFM is a remarkably sensitive detector that can be

used to detect separated components. These diverse functional components of microfluidic manipulation have been combined in this work to demonstrate AFM mediated chromatography.

AFM mediated chromatography uses channel-less, shear-driven pumping. This is demonstrated with a thin, aluminum oxide substrate and a non-polar solvent system to separate a mixture of lipophilic dyes. In conventional chromatographic terms, this is analogous to thin-layer chromatography using normal phase alumina substrate with shear-driven pumping provided by the AFM tip-cantilever mechanism. The AFM detection of separated components is accomplished by exploiting the variation in the localized friction of the separated components. The AFM tip-cantilever provides the mechanism for producing shear-induced flows and rapid pumping.

Shear-driven chromatography (SDC) is a relatively new concept that overcomes the speed and miniaturization limitations of conventional liquid chromatography. SDC is based on a sliding plate system, consisting of two flat surfaces, one of which has a recessed channel. A fluid flow is produced by axially sliding one plate past another, where the fluid has mechanical shear forces imposed at each point along the channel length. The shear-induced flow rates are very reproducible, and do not have pressure or voltage gradient limitations.

SDC opens up a new range of enhanced separation kinetics by permitting the sample confinement with sub-micron dimensions. Small, highly confined liquid is advantageous for chromatographic separation because the separation rate is known to scale according to the square of the confined

sample diameter. In addition, because shear-driven flows are not limited by fluid velocity, shear-driven liquid chromatography may provide up to 100,000 plate efficiency.

This work was done by Mark S. Anderson of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-48647, volume and number of this NASA Tech Briefs issue, and the page number.



Sample Analysis at Mars Instrument Simulator

A novel tool will optimize and validate science operation plans of the instrument on the surface of Mars with a turnaround time of a few hours instead of multiple days.

Goddard Space Flight Center, Greenbelt, Maryland

The Sample Analysis at Mars Instrument Simulator (SAMSIM) is a numerical model dedicated to plan and validate operations of the Sample Analysis at Mars (SAM) instrument on the surface of Mars. The SAM instrument suite, currently operating on the Mars Science Laboratory (MSL), is an analytical laboratory designed to investigate the chemical and isotopic composition of the atmosphere and volatiles extracted from solid samples. SAMSIM was developed using Matlab and Simulink libraries of MathWorks Inc. to provide MSL mission planners with accurate predictions of the instrument electrical, thermal, mechanical, and fluid responses to scripted commands. This tool is a first example of a multi-purpose, full-scale numerical modeling of a flight instrument with the purpose of supplementing or even eliminating entirely the need for a hardware engineer model during instrument development and operation.

SAMSIM simulates the complex interactions that occur between the instrument Command and Data Handling unit (C&DH) and all subsystems during the execution of experiment sequences. A typical SAM experiment takes many hours to complete and involves hundreds of components. During the simulation, the electrical, mechanical, thermal, and gas dynamics states of each hardware component are accurately

modeled and propagated within the simulation environment at faster than real time. This allows the simulation, in just a few minutes, of experiment sequences that takes many hours to execute on the real instrument.

The SAMSIM model is divided into five distinct but interacting modules: software, mechanical, thermal, gas flow, and electrical modules. The software module simulates the instrument C&DH by executing a customized version of the instrument flight software in a Matlab environment. The inputs and outputs to this synthetic C&DH are mapped to virtual sensors and command lines that mimic in their structure and connectivity the layout of the instrument harnesses. This module executes, and thus validates, complex command scripts prior to their up-linking to the SAM instrument. As an output, this module generates synthetic data and message logs at a rate that is similar to the actual instrument.

The mechanical module simulates the actions of a number of mechanical components of the SAM instrument. This module contains the valves, the pumps, and the Sample Manipulation System (SMS). The response of each of these elements is modeled to produce outputs of state variables (velocity, position, force, etc.) that duplicate the behavior of the real elements.

The thermal module simulates the action of ≈ 60 heaters and their local thermal impact on the instrument. It also predicts the individual temperatures sensed by ≈ 70 thermistors and transmitted to the C&DH.

The gas flow module simulates the gas dynamics (time-dependent pressures and gas flows) in the Gas-Processing System (GPS) of SAM. The conductance of each gas transfer element (pipe, manifold, leak, pump, etc.) is dynamically computed as a function of the component dimension, gas composition, pressure, and temperature.

The electric module captures the electrical behavior of motors, control boards, Bayard-Alpert gauges, detectors, valves, heaters, and all components that contribute to the instrument power profile.

The behavior of each element of the SAMSIM model is reconstructed by accounting for all the relevant modules to that element. Complex components like pumps integrate contributions from modules to simulate the evolution of their command logic, rotor speeds, currents, temperatures, and throughputs.

This development was conducted by Mehdi Benna of the Center for Research and Exploration in Space Science & Technology (CREST) at Goddard Space Flight Center and Tom Nolan of Nolan Engineering, LLC. Further information is contained in a TSP (see page 1). GSC-16566-1

Access Control of Web- and Java-Based Applications

NASA's Jet Propulsion Laboratory, Pasadena, California

Cybersecurity has become a great concern as threats of service interruption, unauthorized access, stealing and altering of information, and spreading of viruses have become more prevalent and serious.

Application layer access control of applications is a critical component in the overall security solution that also includes encryption, firewalls, virtual pri-

vate networks, antivirus, and intrusion detection. An access control solution, based on an open-source access manager augmented with custom software components, was developed to provide protection to both Web-based and Java-based client and server applications.

The DISA Security Service (DISA-SS) provides common access control capabilities for AMMOS software applica-

tions through a set of application programming interfaces (APIs) and network-accessible security services for authentication, single sign-on, authorization checking, and authorization policy management.

The OpenAM access management technology designed for Web applications can be extended to meet the needs of Java thick clients and stand-

alone servers that are commonly used in the JPL AMMOS environment. The DISA-SS reusable components have greatly reduced the effort for each AMMOS subsystem to develop its own access control strategy.

The novelty of this work is that it leverages an open-source access management product that was designed for Web-

based applications to provide access control for Java thick clients and Java standalone servers. Thick clients and standalone servers are still commonly used in businesses and government, especially for applications that require rich graphical user interfaces and high-performance visualization that cannot be met by thin clients running on Web browsers.

This work was done by Kam S. Tso and Michael J. Pajewski of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

The software used in this innovation is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48435.

Tool for Automated Retrieval of Generic Event Tracks (TARGET)

A generalized algorithm implementation is applied to scientific data sets for establishing events, such as tornadoes, both spatially and temporally.

Goddard Space Flight Center, Greenbelt, Maryland

Methods have been developed to identify and track tornado-producing mesoscale convective systems (MCSs) automatically over the continental United States, in order to facilitate systematic studies of these powerful and often destructive events. Several data sources were combined to ensure event identification accuracy. Records of watches and warnings issued by National Weather Service (NWS), and tornado locations and tracks from the Tornado History Project (THP) were used to locate MCSs in high-resolution precipitation observations and GOES infrared (11-micron) Rapid Scan Operation (RSO) imagery. Thresholds are then applied to the latter two data sets to define MCS events and track their developments.

MCSs produce a broad range of severe convective weather events that are significantly affecting the living conditions of the populations exposed to them. Understanding how MCSs grow and develop could help scientists improve their weather prediction models, and also provide tools to decision-makers whose goals are to protect populations and their property.

Associating storm cells across frames of remotely sensed images poses a difficult problem because storms evolve, split, and merge. Any storm-tracking method should include the following processes: storm identification, storm tracking, and quantification of storm intensity and activity.

The spatiotemporal coordinates of the tracks will enable researchers to obtain other coincident observations to conduct more thorough studies of these events. In addition to their tracked locations, their areal extents, precipitation intensities, and accumulations — all as functions of their evolutions in time — were also obtained and recorded for these events. All parameters so derived can be catalogued into a moving object database (MODB) for custom queries.

The purpose of this software is to provide a generalized, cross-platform, pluggable tool for identifying events within a set of scientific data based upon specified criteria with the possibility of storing identified events into a searchable database. The core of the application uses an implementation of the connected component labeling (CCL) algo-

rithm to identify areas of interest, then uses a set of criteria to establish spatial and temporal relationships between identified components. The CCL algorithm is used for identifying objects within images for computer vision. This application applies it to scientific data sets using arbitrary criteria.

The most novel concept was applying a generalized CCL implementation to scientific data sets for establishing events both spatially and temporally. The combination of several existing concepts (pluggable components, generalized CCL algorithm, etc.) into one application is also novel. In addition, how the system is designed, i.e., its extensibility with pluggable components, and its configurability with a simple configuration file, is innovative. This allows the system to be applied to new scenarios with ease.

This work was done by Thomas Chune of Goddard Space Flight Center; Shawn Freeman, Carlos Cruz, and Robert Burns of Northrop Grumman; Kwo-Sen Kuo of Caelum Research Corporation; and Jules Kouatchou of TetraTech AMT. Further information is contained in a TSP (see page 1). GSC-16665-1

Bilayer Protograph Codes for Half-Duplex Relay Channels

The proposed code is constructed by synthesizing a bilayer structure with a protograph.

NASA's Jet Propulsion Laboratory, Pasadena, California

Direct to Earth return links are limited by the size and power of lander devices. A standard alternative is provided by a two-hops return link: a proximity link (from lander to orbiter relay) and a deep-space link (from orbiter relay to Earth). Although direct to Earth return

links are limited by the size and power of lander devices, using an additional link and a proposed coding for relay channels, one can obtain a more reliable signal. Although significant progress has been made in the relay coding problem, existing codes must be painstakingly op-

timized to match to a single set of channel conditions, many of them do not offer easy encoding, and most of them do not have structured design.

A high-performing LDPC (low-density parity-check) code for the relay channel addresses simultaneously two important

issues: a code structure that allows low encoding complexity, and a flexible rate-compatible code that allows matching to various channel conditions. Most of the previous high-performance LDPC codes for the relay channel are tightly optimized for a given channel quality, and are not easily adapted without extensive re-optimization for various channel conditions. This code for the relay channel combines structured design and easy encoding with rate compatibility to allow adaptation to the three links involved in the relay channel, and furthermore offers very good performance. The proposed code is constructed by synthesizing a bilayer structure with a protograph. In addition to the contribution to relay encoding, an improved family of protograph codes was produced for the point-to-point AWGN (additive white Gaussian noise) channel whose high-rate mem-

bers enjoy thresholds that are within 0.07 dB of capacity.

These LDPC relay codes address three important issues in an integrative manner: low encoding complexity, modular structure allowing for easy design, and rate compatibility so that the code can be easily matched to a variety of channel conditions without extensive re-optimization. The main problem of half-duplex relay coding can be reduced to the simultaneous design of two codes at two rates and two SNRs (signal-to-noise ratios), such that one is a subset of the other. This problem can be addressed by forceful optimization, but a clever method of addressing this problem is via the bilayer lengthened (BL) LDPC structure. This method uses a bilayer Tanner graph to make the two codes while using a concept of "parity forwarding" with subsequent successive decod-

ing that removes the need to directly address the issue of uneven SNRs among the symbols of a given codeword. This method is attractive in that it addresses some of the main issues in the design of relay codes, but it does not by itself give rise to highly structured codes with simple encoding, nor does it give rate-compatible codes. The main contribution of this work is to construct a class of codes that simultaneously possess a bilayer parity-forwarding mechanism, while also benefiting from the properties of protograph codes having an easy encoding, a modular design, and being a rate-compatible code.

This work was done by Dariush Divsalar of Caltech, and Thuy Van Nguyen and Aria Nosratinia of the University of Texas at Dallas for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47539

➤ Influence of Computational Drop Representation in LES of a Droplet-Laden Mixing Layer

For numerical simulations of such flows, fine-grid LES is not as accurate as coarse-grid LES.

NASA's Jet Propulsion Laboratory, Pasadena, California

Multiphase turbulent flows are encountered in many practical applications including turbine engines or natural phenomena involving particle dispersion. Numerical computations of multiphase turbulent flows are important because they provide a cheaper alternative to performing experiments during an engine design process or because they can provide predictions of pollutant dispersion, etc. Two-phase flows contain millions and sometimes billions of particles. For flows with volumetrically dilute particle loading, the most accurate method of numerically simulating the flow is based on direct numerical simulation (DNS) of the governing equations in which all scales of the flow including the small scales that are responsible for the overwhelming amount of dissipation are resolved. DNS, however, requires high computational cost and cannot be used in engineering design applications where iterations among several design conditions are necessary. Because of high computational cost, numerical simulations of such flows cannot track all these drops.

The objective of this work is to quantify the influence of the number of computational drops and grid spacing on

the accuracy of predicted flow statistics, and to possibly identify the minimum number, or, if not possible, the optimal number of computational drops that provide minimal error in flow prediction. For this purpose, several Large Eddy Simulation (LES) of a mixing layer with evaporating drops have been performed by using coarse, medium, and fine grid spacings and computational drops, rather than physical drops. To define computational drops, an integer N_R is introduced that represents the ratio of the number of existing physical drops to the desired number of computational drops; for example, if $N_R=8$, this means that a computational drop represents 8 physical drops in the flow field. The desired number of computational drops is determined by the available computational resources; the larger N_R is, the less computationally intensive is the simulation. A set of first order and second order flow statistics, and of drop statistics are extracted from LES predictions and are compared to results obtained by filtering a DNS database. First order statistics such as Favre averaged stream-wise velocity, Favre averaged vapor mass fraction, and the drop stream-wise velocity, are predicted

accurately independent of the number of computational drops and grid spacing. Second order flow statistics depend both on the number of computational drops and on grid spacing. The scalar variance and turbulent vapor flux are predicted accurately by the fine mesh LES only when N_R is less than 32, and by the coarse mesh LES reasonably accurately for all N_R values. This is attributed to the fact that when the grid spacing is coarsened, the number of drops in a computational cell must not be significantly lower than that in the DNS.

Results indicate that for large N_R values, the fine-grid LES is not as accurate as coarse-grid LES, besides being computationally more intensive. This is attributed to the fact that a fine-grid LES used in conjunction with a reduction in the number of followed drops from the physical to a computational drop field implies that there is necessarily a smaller number of drops in a computational cell than in DNS; this aspect naturally influences the flow development and biases it from the filtered DNS. The key to success seems to be having approximately the same and not a significantly smaller number of drops in the computational cell volume in LES as compared to those

in DNS. Thus, the notion that smooth statistics are all that is required in the choice of the number of computational drops does not hold. This is because unlike particles in a Monte-Carlo calculation where the number of these tracked particles would be increased to obtain

convergence of results, drops are not stochastic particles as they obey a deterministic trajectory that is only modulated by turbulence. This finding also highlights the importance of obtaining drop-number experimental data in combustion chambers or natural flows.

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